NEW ENGLAND WATER WORKS ASSOCIATION.

ORGANIZED 1882.

Vol. II. June, 1888. No. 4.

This Association, as a Body, is not responsible for statements or opinions of any of its members.

ADJOURNED MEETING.

FEBRUARY, 15th, 1888.

The February meeting of this society was held in Boston, at Young's Hotel, on Wednesday, the 15th inst., and was attended by 65 members, and guests, with President Darling in the chair, and a more sociable and thoroughly enjoyable gathering has rarely been known in the history of the Association.

Dinner was served at 1:30 o'clock, and when cigars had been lighted President Darling called the company to order, and called upon the Secretary to read the names of the applicants for membership who had been approved by the Executive Committee, and the Secretary was instructed by vote to cast the vote of the Association for the following gentlemen:

Active—Geo. Alexander, President Water Company, Bath, Me., J. W. Ringrose, Secretary, New Britain, Conn.; Geo. E. Evans, C. E., Lowell, Mass.; R. A. Hale, Hydraulic Engineer, Lawrence, Mass.

Associate—Frank B. Durfey, Contractor, Norwich, Conn.; J. Henry Wells, Boston.

On motion of Mr. Baldwin, Mr. E. R. Jones, the veteran Superintendent of the Eastern Division of the Boston Water Works, was elected an honorary member, and the gentleman returned his thanks in a few well chosen words.

The President announced the topic assigned for discussion to be "Water Waste, with Especial Reference to the Amount Used During the Winter Months, to Prevent Freezing."

Commissioner Hawes, of Fall River, said they had 400 frozen services at the present time, but were not using as much water as one year ago. The consumption had steadily decreased for several years in spite of the large increase of new takers, and was perhaps attributable to the use of meters whereby the department was paid for all water whether used or wasted. They had no trouble with freezing of meters if set according to requirements.

Asst. Engineer Dexter Brackett, of the Boston department said that during three or four of the coldest days of the present winter, the daily consumption of water had increased to 70,000,000 gallons, as against 35,000,000 gallons average daily consumption for the month of November, showing

that one-half of the water furnished was to meet the enormous waste due to the effort on the part of the water takers to prevent freezing.

He cites figures from experiments made in 1881-2, showing a consumption in a section of the city having a population of 2860 persons using an average of 27½ gallons per capita on a day of ordinary temperature (Dec. 23)and on an exceedingly cold day (Jan. 24) 61 gallons per capita. During the nights above mentioned the figures increased from 9 gallons to 52 gallons per capita. Later in the month, the consumption increased from 27 gallons to 100 gallons per capita and the night rate was raised from 9 to to 89 gallons. The causes for the waste he attributed to poor plumbing and he had found no way to stop it, but there was this consolation that it came at a season of the year when the water supply was unusually abundant.

The loss of head from Mystic reservoir to East Boston during the recent cold weather was about 63 feet and from Chestnut Hill to the city about 35 feet. The ordinary loss of head is about 20 feet less than the above figures, showing that the loss of head is more than doubled by allowing water to waste to prevent freezing of services.

Supt. Hyde of Newton, reported that their consumption had not been materially increased, because of the general use of meters in that city.

Supt. Kent, of Woonsocket, R. I., was obliged to encourage waste in order to keep their pipes and hydrants from freezing. He found frost from 5 to 7 feet deep, and in order to meet the increased demand for water had been obliged to run his pumps 16 hours a day as against six ordinarily.

Supt. Coggeshall, of New Bedford, reported an increase in excess of former years, although they had been troubled but little with freezing of services.

Supt. Nevons, of Cambridge, did not want to stop waste, in fact the Water Board, in 1875, had issued a notice asking people to allow the water to run to avoid freezing. They had several hundred feet of 4 and 6 in. pipe frozen during the present winter and had not yet found a way to prevent waste.

Supt. Darling, of Pawtucket, found that the use of metres protected his department against excessive waste; the season had been unusually severe, and frozen services had been numerous. He found that in the warm days the frost penetrated the ground more effectually than in the colder ones, and they had found it in places 6½ feet below the surface.

Supt. Jones, of Boston, detailed the various attempts to prevent waste in the city as follows: 1st. Night inspection with a large force of men, which had proved a failure. 2nd. Fining every one detected in allowing water to run when not actually in use. This method raised serious difficulties and was abandoned. If waste must continue, he would advise large mains and let it run. The present season he thought less severe than in 1874-5, when he had 2,000 frozen services at one time. Men who knew how to thaw pipes were not numerous enough to supply the demand at the time named, and the department was obliged, for the first time in its history, to issue permits to plumbers to dig up the streets. He favored, as the best method of thawing, the cutting of the service inside the cellar wall and putting in a ¾ inch round way cock and then using a $\frac{1}{16}$ inch block tin pipe, 50 feet in length, with funnel attached, into which hot

water was poured,and as fast as the ice was thawed the pipe was pushed into the service. This had been found a very quick and satisfactory method of thawing if the services were straight.

Supt. Billings, of Taunton, reported an increase in pumping in his city and gave a comparison between the hours of from 6 P. M. to 6. A. M., for the month of November as against some of the several days of January, showing the increase to be from 176,000 gallons to 413,000 per night. He would like to stop waste, but knew of no method except the purchase of 1,000 or more meters, which under present conditions was not advisable.

Sec'y Knapp, of Lowell, reported that their meter bills had been largely increased during the winter, and in some cases the figures were five-fold greater than before. He asked the opinion of those present as to the advisability of making abatements in such cases; but the sentiment of all seemed to be adverse to such a course.

Mr. Parker, of Burlington, Vt., has decided that the only way for them to prevent frozen services is to put them below frost, and now covers all pipes with six feet of earth, and if a pipe is found to be frozen it is let alone until spring and is then relaid to a proper depth.

Other remarks were made by Supt. Stacy, of Marlboro; Cochrane, of Nahant; Thomas, of Lowell; Registrar Glover of Newton; Supt. Lockwood, of Yonkers, N. Y., and others.

The following gentlemen were present:

C. F. Allen, Treasurer, Hyde Park, Mass.; J. Henry Brown, Supt., Charlestown, Mass.; Dexter Brackett, Asst. City Eng., Boston, Mass., E. R. Jones, Supt., Boston, Mass.; W. C. Boyce, C. E., Worcester, Mass.; C. H. Baldwin, Boston, Mass.; Phineas Ball, C. E., Worcester Mass.; W. R. Billings, Supt., Taunton, Mass., R. C. P. Coggeshall, Supt., New Bedford, Mass.; Edwin Darling, Supt., Pawtucket R. I.; A. B. Drake, New Bedford, Mass.; F. F. Forbes, Supt., Brookline, Mass.; F. L. Fuller, C. E., Boston, Mass., A. S. Glover, Registrar, West Newton, Mass.; Benjamin Grush, Supt, Salem, Mass.; John Harris, Waltham, Mass.; E. A. W. Hammett, C. E., Boston, Mass.; H N. Hyde, Jr., Supt., Newton, Mass.; H. G. Holden, Supt., Nashua, N. H.; W. M. Hawes, Fall River, Mass.; J. L. Harrington, Cambridge, Mass.; H. H. Knapp, Clerk, Lowell, Mass.; F. E. Hall, Supt., Quincy, Mass., Jos. A. Lockwood, Supt., Yonkers, N. Y.; A. F. Noyes, City Eng., West Newton, Mass.; Hiram Nevons, Supt., Cambridge, Mass.; J. H. Perkins, Supt., Watertown, Mass.; A. G. Pease, Supt., Spencer, Mass.; F. H. Parker, Supt., Burlington, Vermont; Geo. J. Ries, Supt, E. Weymouth, Mass.; A. H. Salisbury, Supt., Lawrence, Mass.; F. P. Stearns, Chief Eng. State Board of Health, Boston, Mass.; Geo. A. Stacy, Supt., Marlboro, Mass.; Solon M. Smith, Supt., Grafton, Mass.; C. H. Truesdale, Quincy, Mass.; D. N. Tower, Supt. Cohassett, Mass.; M. M. Tidd, C. E., Boston, Mass., L. A. Taylor, C. E., Boston, Mass.; W. C. Wilcox, Waltham, Mass.; S. J. Winslow, Supt., Pittsfield, N. H.; Geo. E. Winslow, Supt.. Waltham, Mass.; C. K. Walker, Supt., Manchester, N. H.; H. B. Winship, Norwich, Conn.

Associate—H. A. Gorham, Boston, Mass.; E. M. Bixby, Boston, Mass.; H. F. Jenks, Pawtucket, R. I.; J. P. K. Otis, Worcester, Mass.; B. Frank

Polsey, Boston, Mass., F. E. Stevens, Boston, Mass.; C. W. Talcott, Woonsocket, R. I.; George Woodman, Boston, Mass.

Guests—Mr. Welch; E. T. Wirwell, Newton, Mass.; X H. Goodnough, Boston, Mass.; Mr. Gardner, Salem, Mass.; Mr. Brown, Salem, Mass.; Mr. Watts, Lawrence, Mass,; Mr. Johnson, Boston, Mass.; Mr. E. D. Holden, Lowell, Mass.; R. J. Thomas, Supt., Lowell, Mass.; Mr. E. D. Conant.

QUARTERLY MEETING, AT BOSTON,

March 14th, 1888.

The March meeting of this Association was held at Young's Hotel, Boston, on Wednesday, March 14th. The meeting was called to order at 12.30 by President Darling and the following members were present.

Vice Presidents, FitzGerald of Boston. and Kent of Woonsocket.

Senior Editor, Prof. Swain of Boston.

Secretary Coggeshall of New Bedford.

Treasurer Glover of Newton.

Jones of Boston, Hall of Quincy, Noyes of Newton, Beals of Middleboro, Brown of Charlestown, Baldwin of Boston, Bickford of Boston, Fuller of Boston, Forbes of Brookline, Gerry of Stoneham, Grush of Salem, Hale of Lawrence, Hawes of Fall River, Holden of Nashua, Hyde of Newton, Kieran of Fall River, McClintock of Chelsea, Ries of East Weymouth, Robertson of Fall River, Stearns of Boston, Swan of Boston, Taylor of Boston, Truesdale of Quincy, Watters of Fall River, Winslow of Waltham.

Brodrick of Chadwick Lead Works.

French of National Tube Works.

Gilchrist of Gilchrist & Gorham, Boston.

Polsey of Walworth Manfg. Co.

Tilden of Hersey Meter Co.

Geo. Woodman.

The Guests were as follows:

Prof. Wm. T. Sedgwick of Mass. Inst. of Technology.

E. K. Dunham, Biologist of State Board of Health.

S. W. Abbott, Secretary of State Board of Health.

F. Brooks of Boston, X. H. Goodnough of Boston, H. Burr, President Common Council, West Newton, E. T. Wirwell of Newton, R. J. Thomas of Lowell, Geo. Bowers of Lowell, Paul B. Patten of Salem, J. G. Dennett of Beverly, Mr. Humphrey of East Weymouth.

The Secretary read the following list of names of applicants for membership in the Association, all of whom had been considered and favorably reported upon by the Executive Committee.

FOR RESIDENT ACTIVE MEMBERS.

Willis E. McAllister, Superintendent, Calais, Maine.

John F. Philbin, Water Registrar, Clinton, Mass.

D. A. Harris, Superintendent, New Britain Conn.

FOR NON RESIDENT ACTIVE MEMBERS.

Whitney Conant, Secretary, Long Branch, N. J.

On motion the Secretary was directed to cast the vote of the Association for the list as read, which he did, and the Chairman declared the gentlemen whose names had been read, elected members of the Association.

Lunch was announced at one o'clock. After cigars had been lighted, President Darling introduced Prof. William T. Sedgwick of the Massachusetts Institute of Technology, who read a carefully prepared paper upon

THE BIOLOGICAL EXAMINATION OF WATER.

By William T. Sedgwick, Ph. D.

Professor of Biology in the Massachusetts Institute of Technology.

Within the past five and twenty years a new theory of the causation of infectious diseases has sprung up and given to the medical sciences an aspect more rational, more scientific and more hopeful. Upon sanitary science the effect of the new theory has been still more vivifying; indeed, it is hardly too much to say that sanitary science, so far as it exists practically, has been by it created. Under the older theories of the causation of disease which saw in bodily disturbances only the effects of malign influences exerted by evil spirits; or regarded health as the proper mixture of four internal humors—blood, phlegm, yellow bile and black bile,—and looked upon the improper mixture of these four humors as constituting the basis of all diseases, sanitary science obviously found no place. But as soon as it began to be recognized that the seeds of disease are not so much in us as in our environment; that the blind experience of the race as shown by the ideas and language everywhere employed in speaking of the "attacks" of disease had outrun the theories of the wise, recognizing instinctively the true sources of disease as extrinsic, rather than intrinsic; or, in other words, as soon as the original source of disease was perceived to be, not *in* us, but *around* us, sanitary science became at once a possibility and a necessity. In his essay upon the "Advisableness of Improving Natural Knowledge", Professor Huxley has given a forcible example of the attitude of mind which prevailed towards sanitary matters under the older theories of disease, where he contrasts the panic-stricken and awed submission of the dwellers of London to the visitations of the Plague with their angry passion at the incendiaries who were believed by them to have caused the great fire which not long after devastated their city. To the plague they submitted devoutly and helplessly as to a visitation of the Almighty; to the fire they did not so submit but, full of indignation, sought to find, and rid themselves of, the cause.

Obviously, therefore, it is not a matter of indifference to sanitarians, among whom should be included those having the control or administration of water supplies, whether this theory or that of the causation of disease is entertained. Every officer and every workman connected with such positions of responsibility is guided, consciously or unconsciously, by

some working theory which determines more or less his attitude towards his professional problems; and those best informed are today making good use of the so-called "germ" theory of disease. This theory holds that the ordinary infectious diseases such as typhoid fever, small pox and measles are caused by microscopic plants or "*germs*" called *bacteria* or *microbes* or *micro-organisms*, which when they invade or "attack" the human body may do infinite damage, producing sometimes disease and even death. They behave as parasites, feeding upon the tissues, multiplying enormously and producing profound and alarming changes in the bodily economy; yet doing their damage not so much by their presence or, like most parasites, by stealing from the body its necessary foods but rather by *poisoning* it, unintentionally as it were, by their excreta or the by-products of their activity which though little understood as yet, are provisionally grouped together under the name of "Ptomaines." Accordingly, bearing this "germ" theory in mind, sanitarians have always to scrutinize the environment of individuals and communities in cities, in the country, in workshops, in theatres, on land or sea. Wherever man goes he finds himself in an environment which may or may not contain the seeds of disease, or, more rarely, the poisonous excreta of the organisms of disease. Air, food and drink naturally carry with them the greatest possibilities of infection, since they are received within the body in special chambers—the lungs, and the other portions of the alimentary tract—specially delicate and adapted for absorption. With the air and the solid food we have at present nothing to do. With the purity of water however we are much concerned.

Biological examinations of water have been made to some extent ever since the human race began. Multitudes of observers have noticed, and some few have studied the fishes and frogs, serpents, snails, clams and crustacea which inhabit ponds, streams, lakes and the sea. Others have studied the water-weeds, the sea-weeds, the algæ and the fungi, and have thus helped to a knowledge of the biology of water. But it is only within a very few years that it has been thought either possible or necessary to count or study the smallest of all the forms of life, the "germs," "bacteria," etc., in water. That our opinions in this respect have changed, is due partly to the adoption of that environmental and parasitic theory of infectious disease of which we have just spoken, bringing with it as it does the recognition that these tiny and invisible organisms may be the agents of disease; and partly to a new and similar theory of putrefaction which teaches that wherever putrefaction is, there will germs be gathered together. I must hasten however to warn you that there are germs and germs. Because there are some blacklegs in human society it does not follow that all men are such. And yet some pseudo-sanitarians whose object is best served by widespread dismay and alarm, sedulously endeavor to impress the public with the idea that germs are everywhere, and that all germs are dangerous.

There is such a thing, however, as slandering bacteria; for while some of them are unquestionably dangerous, and, in the present state of our ignorance about the different species, all of them are more or less under a

shadow, there is not the slightest doubt that we depend almost wholly upon bacteria for the reduction to harmless compounds of the great mass of waste organic stuff in nature. If, then, bacteria abound in the waters of our harbor and bay it is not necessarily with evil intent or with danger to us, but simply because they find there the waste matters of a great city rejected by higher forms of life, but offering to them, the lowliest of living things, an ample feast. In fact, bacteria would seem to possess a wonderful and most beneficial power of reducing to their lowest terms those fractions of organic matter which higher forms are unable entirely to simplify; thereby at once ridding the earth of a nuisance and preparing the way for higher plants to effect a rejuvenation of the worn out matter. Again, precisely as it is not true that all germs are deadly or the carriers of disease, it is equally certain that they are not ubiquitous, nor are they always long lived. They are heavy in proportion to their size, and hence tend to sink in air or water; they are very dependent on food and drink and therefore may easily be held in check by cleanliness and dryness. In short, while it is easy to dogmatize about them and to portray vividly their possible baneful effects, it should not be forgotten that the human race has developed and prospered in ignorance, and in spite, of them, from the days of savagery until now. Nevertheless, they undoubtedly constitute the chief *raison d'ètre* of modern sanitary science and from every point of view their scientific study is most desirable.

It might naturally be asked at this point, How are these exceedingly minute organisms ever studied or counted? and, Of what use is it to count them? or, finally, What may be legitimately expected from the employment of methods for the biological examination of water, in the shape of practical hints which shall be likely to benefit experts in the science or administration of water works? It will be worth while therefore, to describe, *first*, the methods of the biological examination of water; *second*, to discuss briefly the value of such examinations to pure science; and, *third*, to indicate the importance and value of the application of the results of such examinations to the practical problems of our water supplies.

THE METHODS.

These in principle, are extremely simple; but the art involved is capable of very great refinement and absolutely demands great cleanliness, constant care, scrupulous attention to details, and unlimited patience. The object in view, namely, the determination of the *number* and the *nature* of the germs in a given water must never be forgotten, and the better to secure this end-result everything with which the sample of water is to come in contact must be carefully *sterilized;* that is, all germs must be killed except those favored few which it is desired to study.

In order to illustrate by an example the several steps of the process, I may briefly describe an actual biological analysis of the water supply of Newton, Mass., selected not because it is necessarily typical in its results but simply because it is fresh in my experience.

The city of Newton finds its water supply in a filter basin 1575 feet long, running alongside the Charles River in the town of Needham. The water in the filter basin is pumped by engines in a pumping station near by, to a

reservoir some 4 miles distant on Waban Hill, from which it flows by gravity to all parts of the city.

In the spring of 1887 Mr. S. R. Bartlett and myself made, in the Biological laboratory of the Institute of Technology, a determination of the number of living bacteria and moulds in the water of the Charles River outside the filter basin, the water within the filter basin, in the reservoir on Waban Hill and at the tap in the city of Newton; specimens being carefully taken from the different localities on the same successive days. At the same time Mrs. E. H. Richards and Mr. Bartlett carried on a chemical examination of similar samples in the Institute laboratory of sanitary chemistry. In the course of the investigations 145 biological and 117 chemical analyses were made; and all the work done between April 1 and May 15. The method employed in the biological examination was the well-known gelatine plate-culture method of Koch. The usual accessory apparatus was employed and need not be described. The principle underlying the method is this: By mixing a known volume of the water under examination with a much larger volume of so-called "sterilized nutrient gelatine," the germs in the water are first *separated* somewhat widely from each other in the melted gelatine; and afterwards, when the gelatine has been poured out on a cool plate, carefully levelled, are *kept* separate and isolated by the stiffened mass. They are thus held securely apart, but may still grow and multiply in the nutrient mass, enriched as it is by meat extract, peptone, etc. At first the gelatine appears perfectly clear and pure; but after a day or two, comparatively opaque whitish or yellowish dots or islands may be detected, due to the rapid, though localized, increase of the germs. Each of these, if caused by bacteria, is called a "colony" and is taken to represent one "germ" in the original water, provided the gelatine used was properly sterilized, *i. e.*, freed from all living germs. Moulds have an equally characteristic though different appearance, and thus both may be recognized after a time and the total number of living "germs" in the original sample readily and accurately estimated.

The water brought in for examination was collected and transported with great care in small glass-stoppered bottles holding about 60 c. c. These were carefully cleaned and enclosed in tin canisters made to fit them rather tightly, and all were thoroughly sterilized at 160° C. in the hot air sterilizer. The tin covering prevented any accumulation of dust around the stoppers and allowed without injury considerable knocking about in transportation. In getting the sample of water desired, the bottle was taken from its case, rinsed in the water to be collected, held well under, and filled by lifting the stopper. It was then returned to its tin case and thus conveyed to the laboratory where the culture was made usually within three hours from the time of collection.

Some of the more important results are indicated in the following tables:—

NUMBER OF BACTERIA PER CUBIC CENTIMETRE OF WATER.

1887.	Charles River.	Filter Basin.	Waban Hill Reservoir.	A Tap in Newton.
April 1	315	15		
April 6	267	80	April 11 18	8
April 18	220	48	48	6
April 27	175	40	20	0
May 1	200	15	10	4
May 9	150	64	18	April 29 12
Averages	221	43	23	6

BACTERIOLOGICAL COMPARISON OE THE TAP WATER OF NEWTON AND BOSTON DURING ONE WEEK.

Date.	Colonies per c. c., Newton.		Colonies per c. c., Boston.	
	A	B	A	B
May 6	0	4	48	60
" 7	6	12	30	44
" 8	Sunday.		Sunday.	
" 9	8	14	40	52
" 10	0	4	24	60
" 11	2	4	28	32
" 12	0	8	25	35
" 13	12	15	55	65
Averages.	6		43	

AVERAGE NUMBER OF BACTERIA PER C. C. FOUND AT THE SAME TIME IN THE WATER FROM:—

Newton (tap)	6
Boston (tap on the Back Bay)	43
Mystic (tap in Charlestown)	204
Spot Pond (pond)	38
" " (tap in Medford)	10
Jamaica Plain (Boston High Service)	52

These, then, were the methods and the bare results of their application. Let us see in the second place if, upon scrutinizing and interpreting the results we do not gain something for pure science.

And let us here keep in mind that, other things equal, richness in bacteria indicates organic impurity—scarcity of bacteria organic purity on the principle that "where the carrion is there will the vultures be gathered together;" and further that however harmless these microscopic vultures may be we do not wish either to drink them or have them feed upon us.

The first table shows a constant and considerable difference in the abundance of living bacteria in the several waters examined, and indicates a progressive purity in this respect as the water nears the point of consumption. The largest difference between successive samples is that between the river water and that in the filter basin, and this is easily explained by a consideration of the conditions prevailing in each. The river is an ordinary sluggish stream draining a rather thickly inhabited country and hence is more or less polluted. The filter basin on the contrary, although dug parallel to the river, and near it, probably gets from it little or no water. This comes instead from the ground in the other direction owing to the slope of the adjacent country, and, especially from eight artesian wells driven in its bottom to a depth of thirty feet where they penetrate a quicksand and a gravel overlying bedrock inclined towards the river. Thus it comes to pass that the water in the filter basin is sometimes higher than that in the river and always more constant in temperature; and, this, too, it is fair to suppose, is the reason that the water of the river contained 321 germs per cubic centimetre in April and May, 1887, while that in the filter basin showed only 43. The filter basin, even to the naked eye, is clearer and purer than the river, although it often contains a very considerable amount of filamentous algae, principally Zygnema. It is less easy to explain offhand the progressive decrease of bacteria from the filter basin to the tap. The figures show that of the 43 bacteria which theoretically were drawn by the pumps from the filter basin in every cubic centimetre of water 20, *i. e.*, nearly 50 per cent. were missing in the reservoir, and 37, *i. e.*, more than 85 per cent were missing at the tap. From a biological point of view it seems probable that the stock of organic matter or, in other words, the supply of food for the germs, in this chiefly ground water was originally small and gradually gave out causing the starvation of the greater part of the bacteria. This hypothesis was afterwards surprisingly and unexpectedly strengthened by the results of the chemical examinations simultaneously carried on, which showed a very

pure water in the filter basin and a decline of organic matter from the filter basin to the tap.

No attempt was made to seek out from among these germs, which were doubtless for the most part perfectly harmless and as it turned out even useful—having destroyed most of the organic matter and then either starved to death or having otherwise perished,—no attempt, I repeat, was made to seek out here the germs of disease. But we look forward to the time, perhaps very near, perhaps a long way off, when we can sample the colonies upon the gelatine and say, after microscopic and further biological study, this one is harmless, that one dangerous, and so on. But it is not believed by biologists generally that that time has yet really arrived.

And, now, finally, how can I better exemplify the practical bearing of the whole subject than by a reference to this same study of the Newton water supply. You have seen that this water improved steadily from the filter basin to the tap. The average number of germs in the filter basin was 43—exactly, as it happened, the same number as in water at the same time from a Back Bay (Boston) tap. The average number in the reservoir was 23, and at the tap in Newton 6, per c. c What can this mean except that this particular storage, instead of harming that water actually improved it so that it was in this respect nearly 50 per cent better in the reservoir than in the filter basin, and at the tap more than 85 per cent. better than when it started.

This certainly is a practical demonstration and as an amusing outcome I understand that on the strength of it, or for some other reason, at least one water-seller is to-day actually selling Newton water, admitted to be such, in Boston!

That the chemical analysis did not show an improvement correspondingly great also brings out an interesting point showing the superiority of the biological test in one respect and its inferiority in another. For *living germs of this particular class* it is trustworthy—and these are of the chiefest importance; but for dead germs, and for infusoria, crustacea, rotifers, worms, algae and the like it is worthless—and hence the superiority in some respects of the chemical examination. I cannot doubt that when we have gone further we shall be able to answer questions of the highest importance, as to the needs and the merits of closed or open filter galleries or basins, for special cases; the storage of surface waters; the best means of the disposal of sewage; filtration; aeration; and others of like nature—work which our excellent and progressive Massachusetts State Board of Health has already actively undertaken and placed in competent hands.

I have so far spoken only of the *bacteriological* investigation of water including in it the study of moulds. This is only a part—though doubtless, at present, the more important part—of the biological examination for which it is often used as a synonym.

We have yet a great deal to learn however, about the algae, the sponges, the infusoria the rhizopods and the higher forms of life which inhabit or infest (as you please) the sources of our water supply. These are the things which pave the way for bacteria by supplying them with food in the shape of their

own dead bodies or their excreta, as organic matter subject to be decomposed. And yet these same organisms are not by any means wholly bad—they, too, in some cases, at least, remove from the waters undesirable matters, so that to praise or condemn in any given case, requires all the knowledge, the skill and the common sense that an expert biologist can command. Moreover this is a field almost unworked—since chemists, bacteriologists and biologists must here go hand in hand, and these experts have as yet hardly come to recognize, each the other's importance. Still less, of course, do water boards or private citizens in general, understand or recognize the grave importance of such problems; and meanwhile, gentlemen, science, while it offers to you freely whatever it has to give, at the same time depends upon you almost wholly to see to it that its best thoughts and freshest methods are intelligently applied in the practice of every day.

REMARKS OF DR. E. K. DUNHAM.

Mr. President and gentlemen:—I have been requested to place before you some of the figures I have obtained for waters in this neighborhood. I was encouraged to do so by the statement you were all used to figures and rather enjoyed them, so I ask your indulgence for the following. I have classified my results somewhat according to the source of the sample, and I have arranged them in a particular order for a reason that will be evident. I have only examined one brook which is presumably uncontaminated. That is a little brook flowing into Horn Pond at Woburn, called Sucker Brook. It is a small stream and flows rapidly, the water being pretty thoroughly mixed, and I have examined it on two occasions, once after a rain of of twenty-four hours, and again at a relatively drier time. The mean or average of three samples taken on the first occasion showed 2396 in one cubic centimetre of the water; the second examination showed 3178.

From this presumably uncontaminated brook I passed to undoubtedly contaminated ones, of which I have five samples. But first to show you how closely the results from the three samples to which I first referred tallied, I will read what I got in each case, the average of them all being 2396: First, 2443; second, 2480; third, 2266. Now, coming to the contaminated brooks I will mention first Cummings Brook, which also flows into Horn Pond at Woburn, from tanneries and other sources of contamination. In that I found 65,507; in Dow's Brook, flowing in the same pond, samples collected the same day contained 62,119. In the Neponset River at Hyde Park, 16,543; in Stacey's Brook, Swampscott, 18,662 on one occasion, 14,018 on another. In a brooklet at Medfield, which flows from a spring not very far from a filter bed for the purification of sewage, I found, about forty feet from the spring, 17,531; and I was told that the brook was subject to abundant contamination from the surface drainage. The spring itself was relatively clean.

Passing from the brooks to the rivers: I found in the Charles River at Dedham, which I examined on three occasions, an average of 97; at Brookline, 76: at Newton, which I have examined but once, only 5. It is not likely that this figure represents the average number of bacteria in the river. It is probably too small owing to the local conditions at the place and time of collection At Waltham, 133; at Watertown, 2224. In the Merrimack: At Lake Village, 364; at Nashua, 7748; at Lowell, above the dam, in the middle of the stream, about a foot from the surface, 8552; at the inlet house, where the water passes into a conduit, 21,001; at Central Bridge, after the river has received considerable material from the city, in the middle of the stream a short distance under the surface, 13,555; at Lawrence, 14,241 above the city, 12,000 below the city.

In open wells I found one case, an uncovered well on the Dedham shore of Cove Bay, Brookline, 1434. This was an open well with an old wooden curb, the water being drawn in a bucket. In another open well I found 2000. This second well was not very far from a pig-sty on one side and a manure heap on another, and about sixty feet from a privy.

In covered wells: At Brookline, water drawn by a wooden pump, 142; at Swampscott, samples from three metal pumps in the town, numbers varying from 1 to 9.

In ponds: Horn Pond; 65 to 70; Winter Pond, 74; Jamaica Pond, 1397; Mystic Lake, 1524; Farm Pond, South Framingham, 89.

In uncovered filter basins: At Newton, 42; at Waltham, 226. In water from the pumping station tap at Newton I found only one. That was the mean of three examinations.

In covered filter basins: At Dedhan,—in the basin, none, at the tap, none; at Watertown—in the basin, 10, at the tap, 3. In all these cases the tap was the one at the pumping station. At Swampscott—in the basin, on one occasion, 1, and at the tap, none; on another occasion, in the basin, 179; and on still another occasion, a few days afterwards, 90. In those two cases the species found were in each case the same. That is, in the sample taken on the first of November, yielding 179, as a mean between 176 and 183, the bacteria were all of one species, with perhaps one or two exceptions, and the same is true of the next sample. I wish to return to this later, when I speak of the interpretation of the results. At Woburn—in the filter basin there was an average of 1½ between two samples. one containing 1, and the other 2; and at the tap an average of one-half. In Brookline—at the tap there were 8 on one occasion, and, on another, 3. At South Framingham—in the filter basin, 13, at the tap 10.

In driven wells. I found at Hyde Park, at the tap, 2, there being no way of getting at the water in the well itself. In the test well, which is a well, I suppose, prepared in exactly the same way as those in actual use, but left unconnected with the pump, in order that samples might be taken from it for examination, I found 9555, almost all of one species. At Westboro', also a driven well, I found six, an average of three samples, 5, 8 and 6 respectively.

In open reservoirs. At Woburn, on one occasion 119, and on another 23; at Brookline, 36; at Newton, 79; at Waltham, 38; at Brookline reservoi

for the Boston supply, 25; at Parker Hill, 9; College Hill, 79; Chestnut Hill 85.

In tank waters. At Brookline, 148 on one occasion, and 50 on another; at Swampscott, 1 and 3.

Those are all the statistics I wish to present to you to-day. And now I should like to pass on to a condsideration of these bacteria in water. I shall begin by trying to sketch in a general way, first, how the bacteria get into a water, and, second, how they get out of it. That is, what natural processes there are for freeing water from bacteria. Let us follow the water in what might be called its life history, let us begin with rain. I have been unable to collect data of examinations of rain water, and have only made a very limited study of the subject myself. But, certainly, after rain has fallen for some time, there are probably very few bacteria in the suqbseunt fall.

Now, when that comparatively pure water reaches the ground, it is immediately in the presence of an enormous number of bacteria, as is shown by the studies on this subject made by a German about a year ago.*

These same studies also show that the number of bacteria in the soil decreases very rapidly below the surface. At a depth of from 3 to 5 meters the number is so small that many samples contain none, and the ground water, in such places, may also be free of them.

I think these studies explain very readily how bacteria get into surface waters. They represeunt the washings from the surface of the ground. As we have seen in the case of covered wells or driven wells, the water that comes in from below, the ground water, is relatively free from bacteria, and that harmonizes very well with these results. It seems as though the conditions for the development of bacteria were unfavorable below the surface of the ground; that is, at a depth of from two and a half to three metres below the surface, and still further down. They are not found there. And to emphasize that still more clearly, I may mention that at the Hygienic Institute in Berlin, there is a well built for experimental purposes with pipes running from the well itself, horizontally into the ground, at various depths. Experiments have been conducted there with cultures of various bacteria, the bacteria being cultivated either in one proper nutrient medium, like this gelatine, or in earth, or whatever substance might be selected, and placed within the pipes mentioned, so as to imitate as nearly as possible the natural condition under ground.

It was found in these experiments that none of the three disease-producing bacteria, anthrax, cholera and typhoid fever throve at a depth of over three metres; after a while they died out. That was especially so in anthrax, and next of cholera; the typhoid bacteria retained its vitality longest of the three.

Let us now, return to the consideration of the water, which has washed the surface of the ground and is running off, let us suppose into a brook. And let us take a specific example, Sucker Brook. When this brook empties into Horn Pond, the conditions of the water are abrubtly

*Carl Frankel, "Untersuchungen uber das Vorkommen von Mikroorganismen in verschiedenen Bodenschichten." Zeitschrift fur Hygiene—Vol, 2, p. 521.

changed. Instead of being a rapidly flowing stream, where all suspended matter is kept in constant agitation with the water, and diffused pretty uniformly through it, the water comes to a sudden stand still, and the suspended matter settles. Now the bacteria are not in solution in the water, but in suspension. They tend to settle. It seems probable that the diminution from the number in the pond,—it being in the case of Sucker Brook from 3000 to 65, and in the case of other brooks from 65,600 to 62,000, respectively, to 65,—is due to this settling. Although these brooks were constantly emptying enormous numbers of bacteria into Horn Pond, the pond water, collected at some distance from these brooks, was relatively clean and free of bacteria.

There is probably a very good example of the way in which settling will purify water from bacteria to be found in some studies of the Spree River at Berlin. The river through the city is about 800 feet wide, I should think. Below the city it widens so that in some places it is as much as a mile wide, or perhaps a trifle over. I have some figures here obtained from different portions of the river, and I will start with some samples taken from the river just as it leaves the city, while it is still narrow. At a place called Spandau there were 230,000; at Gawtow, four miles below, 290,000. Six miles below at Sacross the river having widened very soon after passing Gatow, where there were 290,000, the number had fallen to 4000.

So it seems to me that one of the natural processes of contaminatien is the surface washings; and one of the natural processes of purification is settling.

Another natural process of purification is filtration, and that is exemplified in the ground water in those driven wells, and in the filter basins. I will simply refer to one or two cases of filtration. The water in the filter gallery at Woburn is filtered through the soil and contains an average of one-half a bacterium per cubic centimeter. In the water from the filter Gallery at Dedham no bacteria were found; the river water contained an average of 97. A large number of bacteria in a water may, also, be due to the multiplication of a few individuals which gained admission to the water at some previous time. An example of this I found at Hyde Park, where the ground water was undoubtedly good, judging from the samples taken from the pumping station tap, where the average was two, whereas, in the test well I found over 9000 Now, I judge that this large number was simply due to the multiplication of a few bacteria which had access to the well at some former time and found favorable condition for their development. And this idea is further supported by the fact that the bacteria from the test well were nearly all of one species. Now, that water, containing 9000 germs, provided these germs were innocent, as they undoubtedly were, was perfectly good water. There was no reason why it should not be just as good as the water containing only two; the number was so large simply because of the multiplication, and was no indication that the water came from an unwholesome source. These considerations lead me to infer that the mere numerical study of the bacteria in samples of water is relatively of little consequence. If there is only one germ in a sample water, and that germ

happens to be pathogenic, that water is dangerous; while if there are 10,000 germs which are not pathogenic, and do not indicate a dangerous source, that water is perfectly good.

Now, it seems to me, at least, that we must know more than merely the number of bacteria in order to judge of its fitness for drinking. We must know what kinds of bacteria are there. That is a matter of extreme difficulty, but it seems to me there is a way out of it. If we ask, "whence come the pathogenic germs?" I think we are obliged to say, at least in our present knowledge, that they come from previous cases of disease. We do not know of any natural spot where disease germs naturally live, except in the human body, although some of them are capable of existence in water after they once gain access to it. So the source of danger to drinking water from bacteria, it seems to me, lies chiefly in cases of disease; and it seems that the bacteriological examination of water is capable of sorting out those cases where contamination is from, or possibly from, sources of disease, from those in which it is not. In the case of the uncontaminated brook water, already referred to, the species were such as occur on all vegetation, in dust, etc. In cases of other brooks which are contaminated, the gelatine plates, from which the count was made, had what I should call the "sewage complexion," that is, those species which abound in sewage and in fecal and refuse matter from animals and households were present in great numbers. Such species are not, so far as I know, present in innocent water, such as Sucker Brook water, or an ordinary open well, which is free from contamination. So, if we find a large number of bacteria present, if they are all af one harmless species, or if the sewage forms are absent presumably that water is good. If, on the other hand, the "sewage complexion" was present, I should feel that the water was not safe. And that, it appears true, is about as far as one would care to go now.

But the chemical analysis will help very much in estimating the character of a water. In case of a large number of bacteria of one species, and in case of a large number, perhaps, not of one species, but not of the sewage varieties, if the chemical results were good, then I think the water would be almost free from suspicion. If the chemical nature were bad and the bacteria abundant and of the sewage species, there could hardly be a doubt about the contamination of the water. If bacteriologically the water were good and chemically it were bad, I should be inclined to think the water safe, because I should think it had undergone the necessary purification by filtration. Of course, in streams, where filtration was impossible, this would not hold. So I think that in judging of water, we must study it in three ways: First, by local inspection; second, by chemical examination; third, by bacteriological examination. If the results of all three be favorable, we have no reason to doubt the wholesome nature of the water.

President Darling. I now have the pleasure of presenting Vice-President FitzGerald, who will address you. (Applause.) I would say it almost seems as if there were a conspiracy on the part of our friends to show that Newton has better water than Boston, but knowing the pertinacity of Boston, I

think before we get through we shall learn that Boston water is as good as any other water, as, indeed, we all pretend to say our own water is the best. (Laughter.)

REMARKS OF DESMOND FITZGERALD.

Mr. President and fellow-members:—I don't know exactly why I am brought so prominently into this discussion to-day,—not being a biologist or any other kind of a 'gist that I know of (laughter),—unless it is on the general principle that an engineer ought to be one to be called upon on almost every occasion and on almost every subject. My experience in my profession thus far has been that people seem to think an engineer is supposed to understand every subject from the raising of hay, to the running of a boarding house, the designing of a dam, or making analyses of water. However, it is not just the thing for a man to run away, and so I am going to face the music. Of course you all know I do not know much about this subject, and I propose to keep you but a very few minutes to tell you the little I do know. More than two years ago I became very fully impressed with the belief that the biological examination of water would give us some practical results of value, and I am very glad to notice that the subject has been growing steadily in importance and interest. Of course in this country we have not arrived at the perfection that they have on the other side. We have not the money and facilities for investigation and for original experiment.

You know it is only a few years ago, when we were told that people who caught typhoid fever from drinking certain water from wells, caught it because the wells were polluted with bacteria from the fæces of those who had it, that the reply was made that there was no proof to sustain that statement. And I believe even now that the Germans fight that theory, and take the opposite ground, namely, that almost all diseases, particularly typhoid, come from germ in the air, and not from water. At any rate, I think at the recent congress in Vienna that was the general way in which opinion was divided. France taking the water view, and Germany the air view.

When I was in Paris this summer I had an opportunity to investigate the typhoid germ pretty well from the French standpoint; and through the kindness of M. Pasteur and his principal assistant, Dr. Chantemesse, I had an opportunity to see what they had been doing. It is perfectly clear to my mind from the proof I have seen, that it is entirely possible to say definitely whether in any given specimen of water there are typhoid germs, or whether the water is free from them. This may seem like rather a strong statement, and perhaps it is too strong. I was assured by M. Chantemesse that, in the first place, he was perfectly willing to make the statement that typhoid is a disease produced by micro organisms of specific characteristics only found in the body during the progress of the disease. That of course is a very decided step. But he has gone a step further and found that

whenever anybody has typhoid fever,—I think he said in nine cases out of ten, at least a very large proportion, he has been able to detect the typhoid germ in the body; and after a person begins to recover from the fever, is convalescent, the germ is not found. I think it is generally taken from the spleen.

Then they have gone still another step. They have found that by cultivation of the specific germ by an inoculation, they are able to trace it through the whole progress of its life and observe its effects. I have a full account of their investigations, and I have here some plates. While I was at the Ecole de Medicines I was allowed to examine these colonies in different stages, and they offered me some to bring over, I suppose, however, I can get them here now if I shall care to investigate the matter further. But hereis a view of a colony, just as I saw it under the microscope, and a more active lot of vegetable life I never saw. They all seemed to be hard work, at and Dr. Chantemesse told me that this remarkable activity was one of the characteristics of the bacillus. I had the impression that some of them seemed to be eating the others up. (Laughter.) If they could really do so, I presume it would be a good thing for humanity. I will pass these plates around. In the first place when the germ begins it is a little round transparent dot. Then it puts out litle spores on the side, and after four days' culture it looks like a lot of intestines. Here is another plate that represents six days' culture, and here is another that represents eight days. The specific germs are seen here on this plate. I saw them in different conditions alive, with the spores attached to them and without.

A very interesting fact that Dr. Chanemesse and Dr. Widal, I think, have proved pretty well, is that these can be produced in animals. Of course they haven't had an opportunity to experiment on man yet, but they have inoculated a number of animals, and here is the intestine of a rabbit from Ecole de Médicines. A number of rabbits died, and the germs of the disease were found grouped in little masses in the intestines of the rabbits. I don't know whether that is sufficient proof or not, but the doctors seem to be pretty well satisfied with it.

I was in the South of France at one time during the summer, and at Clermont-Ferront, quite a large and important city, they had an epidemic of typhoid. I was there at the time, but I took very good pains not to drink any of the water, great as is my regard for science. Dr. Chantemesse, who was requested to examine into the case, found the typhoid germs in the water supply. Certainly in one case, where a person, had died he found the same typhoid germ in the body, and also in the water he had been drinking.

Now, that is going a good step in advance, and it seems to me that is what we are coming to in the future here with this biological examination. The subject is a broad one. The very derivation of the word shows it,—*bios*, life, and *logos*, lecture, anything that relates to life whether animal or vegetable. If there are certain disease germs of specific character and we can recognize them, and show that they are in the water, that is a very long step in advance, and I believe that is what we are coming to. Drs. Chantemesse and Widal, I think, have carried this matter further than

almost anybody else; at any rate, I have come across nothing else that seems so definite as their work. They have unusual facilities for experimenting, and I think it would interest all of you if you could see the amount of work they do. In Pasteur's laboratory, I saw more than a hundred people, the morning I was there, come up to be vaccinated for hydrophobia. They took the skin on the side of the patient, pushed it up, put a needle in, and squirted a certain amount of soup containing the germs of hydrophobia, in under the skin. That is done every day for a certain number of days, first on one side then on the other.

In Paris, as you know, they have four sources of supply. The water from the Yonne is very good; the water from the Ourcy, the Seine and the Marne is poor. Dr. Chantmesse has proved by his experiments and by his profiles that whenever the water from the latter sources is let on to the city, the district supplied is sure to be attacked by typhoid fever within a certain time, and the number of cases increases very rapidly. When I was in Paris they got short of the good water, and they were discussing to what district they should supply the poor water that had the typhoid germs; and they had made up their minds, I don't know whether on account of the Democratic administration or not, to let it on to the rich quarter of the city; but there was a good deal of "kicking" and, I suppose, a great deal of influence was brought to bear (laughter), and finally it was let on to one of the poorer districts. I came away before any results were reached, but I presume undoubtedly, the cases of typhoid began to multiply. I have their profiles, and also a great many of their statistics, which I should be very happy to loan to any gentlemen who is interested in the subject. I came away feeling pretty well satisfied that they had carried their experiments to a successful issue, or to a comparatively successful issue, and so far as I was concerned, I was disposed to accept their theories as pretty well proven.

In regard to the Newton water being superior to the Boston water, I am perfectly willing for the time being to admit everything that has been said. But still, in regard to the biological side of the question, I will say I look upon it very much as I do on the chemical side, that is, I think it needs some one who is familiar with the practical side of the subject to interpret the scientific results. An analyses itself does not really give you full knowledge about a water, as you know. It is of great value, but still you must know other things, Of course, if you show by your analyses from time to time that certain things are increasing, that is very valuable, and leads you to seek the cause. But all these things require to be interpreted in the light of practical knowledge. There was one thing that attracted my attention in Prof. Sedgwick's remarks, which I would like to know a little more about. A certain number of these micro organisms were found in the water of the filter basin, a certain number in the reservoir, and a certain number in the tap, and the number from the tap was very small, I think only five or six. Perhaps we can be informed whether the water from the tap had passed through the reservoir.

Prof. Sedgwick. Yes, it had.

Mr. FitzGerald. How did you know it had?

Prof. Sedgwick. It was taken in the city; it was not taken at the pumping station.

Mr. FitzGerald. I would ask Mr. Noyes if some of the water in Newton is not taken directly from the pumps?

Mr. Noyes. It is, and I was going to ask Prof. Sedgwick whether in taking these samples, he took them some little time after the pumps had stopped running. We pump directly into the main, and the surplus goes to the reservoir.

Prof. Sedgwick. That I do not know. All I know is the water was taken from a tap in the city. Whether it actually had gone through the reservoir or not I do not know. I supposed it had and probably gave that impression.

Mr. Noyes. If it was taken some twenty-four hours or more after the pumps had ceased running, then the probabilities are it had passed through the reservoir?

Prof. Sedgwick. The samples were taken usually in the forenoon about nine o'clock.

Mr. Noyes. The pumps are run from two to four days in a week, and the other three to five days the water is drawn from the reservoir.

Mr. FitzGerald. Perhaps it is hardly worth while to pursue the subject, but the idea I mean to convey is we should be careful about drawing any general deductions. It seemed to me, for instance, very curious if water from a filter basin should be taken into an open reservoir, there exposed to the air, and then taken into pipes and distributed and actually be improved by the process. It may be it contains less of these bacilli, but it seems to me that there are other things that come into a determination of the problem. I do not know, but I think as a general rule it will be found that filtered water is hardly improved, hardly made purer, by that process. But, of course, this is of very little value. The main fact remans, that these disease germs are the ones we want to go for, and I hope we will go for them in the future. (Applause.)

President Darling. Now, gentlemen, I have the pleasure of presenting to you a gentleman who is a kind of mediator between us all. He has asked us all to give him samples of water, and he tells each one of us we each have got the best at the present time, that is he thinks so; but at some future time he is going to designate the one that has really got the best water. Mr. F. P. Stearns, Engineer of the Massachusetts State Board of Health, will now address us. (Applause.)

REMARKS OF MR. F. P. STEARNS.

I was asked to say something about this subject, ten days since, and I rather unwittingly said I would. When I began to think what I could say about it, I wished I had said I would not. (Laughter.) I was asked to speak on what may be called the practical side of the question, that is, as to what results we might get that would come directly home to us from

these investigations; and that, perhaps, makes my task even more difficult. When the study of bacteria was first begun, I believe it was purely from a scientific standpoint. The investigators had no idea they were going to determine anything practical; but as an outcome of their studies, they have evolved the theory certain of the diseases are producedby specific bacteria. Whether it is entirely proven now or not, it has at least reached that stage, where many, who have carefully examined it, consider it the most plausible theory ever advanced. I should be very willing to see this method of water examination studied for a number of years, even if we could predict no practical results at all, merely for what might come from it. As Mr. FitzGerald has stated, I think there is this possibility, or this probability, now, that diseases, like typhoid fever, may be carried by bacteria in the water. And it seems to me there is a great chance that we may in the future learn definitely about these matters.

There is very little doubt but that disease is produced by something which may be carried in water. We find a great many instances to prove this. A significant one is the fact that typhoid fever is now looked upon as a country disease. That is, it has been diminishing very much in the cities of late years, and is supposed to be diminishing because of the public water supplies, which are so much better than the old wells. Sometimes in the cities when the water has some peculiar taste, people abandon their public water supply and use the old wells, and then they have an epidemic of typhoid fever, as they did down in Brother Coggeshall's city, a couple of years ago. (Laughter.) Two weeks ago I read in the *Sanitary Engineer* some statistics that had been gathered in Vienna, where the larger part of the city has a very good water supply, and the other part has a very poor one, (somewhat similar to the case Mr. FitzGerald has mentioned with regard to Paris) and these statistics, covering ten years, showed that while, in some years, those that had the pure water had the most typhoid fever, yet this was an exception to the rule, occurring in only one or two years out of the ten. Generally there were more who drank the poor water that had the typhoid fever, and in times of epidemic the ratio was ten to one. That alone is not entirely satisfactory, because it may be that they turned the poorer water on to the poorer quarter of the city, and other unfavorable conditions may have been the cause of the increased amount of this disease. But I saw it stated also that at barracks, where there were soldiers who were under the same conditions in different places except as to water suppiy, those that drank the poorer water had the typhoid fever to a much greater extent, than those who had the pure water. I do not think I need to go further into this subject, for I think it is generally admitted that disease may be transmitted by water.

If it can also be proved that typhoid fever can only be transmitted by means of a typhoid fever germ, then I think we can begin to see some particular ways in which the study of the question may be of great value. For instance, the people of Lawrence would like to know whether typhoid fever or other disease germs, can live long enough in Merrimack River water to come down from Manchester, or from Nashua, or from Lowell, and contaminate their drinking water.

The city of Boston would like to know whether typhoid germs, which may be brought into the southern end of Lake Cochituate with sewage from Natick, will live in that water the weeks and perhaps months required for it to reach the northern end from which it is drawn for use in the city.

Now, it seems to me that the bacteriologists can make laboratory experiments under the proper conditions to give us this knowledge; they can put typhoid fever germs into the Merrimack and Cochituate waters and see how long they will live in them under the most favorable conditrons, and after many such tests, they can add much to our knowledge of the matter.

I suppose as a result of these examinations it is found that these bacteria live and multiply in the waters of our rivers and ponds, the question at once arises, What can we do about it? It is a very simple answer to this question to say we should choose a source that is free from *all* pollution; and where this rule can be followed it is undoubtedly the best one. It is not, however practicable for the city of Boston to find the 100 square miles of watershed needed for its water supply from which no sewage will go into the water and the same is true of many cities and towns around Boston.

I can mention an example where we already have some light from the bacteriologists as to what we *can* do about it.

The sewage of Medfield is turned into the Charles River; they could not put it any where else: twenty miles or more below the water supply of Newton,—Waltham (laughter),—some of the places along there, I guess I had not better specify which,—comes partly from the Charles River by filtration. The sewage of Medfield is put upon a filter bed, instead of being run directly into the stream, and when it goes on to the bed it has about a million bacteria to the cubic centimeter. At a spring where the effluent from the filter bed comes to the surface, two samples showed respectively 100 and 500, and most of these were probably to be attributed to surface water that was running into this spring, as it was a thawing day in winter. If we assume the smaller number to have come through it would mean that 9,999 out of the 10,000 had been filtered out. As we have compared the rivers with the filter galleries beside them, we find the latter contain fewer bacteria, so this is another way in which some of them are taken out. I think we may get important practical results from this study of the removal of bacteria by filtration.

I may say in this conection that the study has been carried on in England to a limited extent by Dr. Percey Frankland. The matter is in the same position that most all new things are, in first process of development, with comparatively little yet from which to draw definite coclusions. Experiments have been made on filtration through a variety of materials, and it has been found that about 99 per cent. of the bacteria can be taken out by slow filtration through sand, coke, charcoal and other substances. Another way of removing them from water is by precipitation with chemicals, the precipitate taking the bacteria down with it. They may not stay down, but it takes them down for a time. I do not think it is a prac-

cal method, still it shows they can be taken out in this way, the same as other suspended matter. In London the filter beds used for filtering the public supply remove from 97 to 99 per cent of the bacteria. In Berlin they remove a great many, and the efficiency of their filter beds is now determined by the percentage of bacteria that go through. I don't know as I need mention any other instances but there are numerous ways in which it seems probable that we can get definite, practical results from the study of bacteria in connection with water supplies. (Applause.)

Mr. FitzGerald. I wish to say one word in connection with what Mr. Stearns has just said, and that is that in Paris they have found that a porcelain filter will take out every typhoid germ. It is impossible for a typhoid germ to pass through the fine pores of an ordinary porcelain filter such as they use in Paris. Dr. Chatemesse assured me he had made a great many experiments, and he has always found it perfectly successful in entirely removing them. In regard to Newton water being peddled here in Boston for spring water, I may say, as an offset to that, we go them one better. We have detected men selling our own water to residents of certain districts as spring water. (Laughter.)

President Darling. It gives me pleasure to call upon Dr. S. W. Abbott, the Secretary of the State Board of Health. (Applause.)

REMARKS OF DR. SAMUEL W. ABBOTT.

I have been very much interested in the discussion that has been going on this afternoon, and also in the previous discussion upon the chemical side of the question. It seems to me that in these two points, and one other, we have the most important questions in connection with water supplies. Three points are necessary in consideration of the purity of any water, and those are the chemical, the biological, and what we may call the practical—that is, the knowledge of where the water comes from and what its surroundings are. When a chemist or biologist is asked to interpret the examination of a water supply as given by him, this practical knowledge is also needed in addition. Of course, a chemist can tell to a certain extent that the water is polluted; but as between the two delicate tests, we will say, where they resemble one another very much, it is not possible for the chemist to say certainly that the water is safe. He may say that a water is unsafe, but he cannot say it is safe. And that is one point we need to bring out, that in addition to the biological and the chemical examination of a water, there should also be a knowledge of its surroundings.

It would be well to understand, also, perhaps, where there may have been a little confusion occasionally, that water is not an originator of disease, not a producer, but simply a medium of contagion; that the contagion is not from the water itself, but something outside of the water that comes into it, and the water is merely the medium through which we obtain the harm. It has been said that wells are more likely to produce typhoid fever than public water supplies. That is certainly true. I do not think any one who has been in country

practice as a physician, for several years, can fail to see that that is certainly so, upon knowing the condition of the wells in the ordinary New England village, or New England farming district, where they are surrounded by everything that is contaminating. But when the *public* water supply does become contaminated, then the danger becomes very much greater. Such things have happened, as when in Plymouth, Penn., the water supply became contaminated, and more than a 1000 cases of typhoid fever broke out in that town of several thousand inhabitants, and more than a hundred persons died. A similar thing occurred in England in 1879 where it was a well known fact that one single case produced the contamination of a water supply. A workman, who had an attack of typhoid fever, who was apparently well, but was really still suffering from the disease, was working in the well and contaminated the water, and six or seven hundred cases occurred in the town immediately afterwards, in the households supplied by that company.

I am very glad you have taken up those two questions and discussed them so thoroughly, that is, the chemical and the biological, and I hope these discussions will be continued, and that you will take still more interest in the subject, and that it may be pursued very thoroughly. Our board is doing all we can in this direction, and I think nothing can be asked more than that the gentlemen here should support the measures that are being taken by the Board, at the request of the Legislature, towards the examination of this subject. It would be proper for me to invite any gentleman here to visit any of the laboratories, especially Dr. Dunham's, and to witness the processes that are conducted there. Or, if you desire to see some of the experiments which are going on at Lawrence at the experimental station, a trip there will repay you very well. We are conducting some extensive experiments there in the purification of sewage. The two questions of water supply and drainage are so intimately connected that they cannot be separated. We must, in order to have our water supplies pure, have good systems of sewerage to keep the sewage out of the water supplies.

On motion of Mr. Coggeshall a vote of thanks was extended to Prof. Sedgwick for his paper, and on motion of Mr. FitzGerald a similar expression was extended Dr. Dunham. After a characteristically humorous address by Mr. Hawes of Fall River, and brief remarks by Mr. Noyes of Newton, the meeting dissolved.

The Secretary was instructed to ascertain if special rates and accommodations could not be procured for the members of this Association in the matter of attendance to the convention of the American Water Works Association at Cleveland next month provided a number sufficient to warrant such action should signify their intention of going.

OBITUARY.

SYLVANUS D. HORTON.

Our fellow-member, Mr. Horton, clerk of the Board of Water Commissioners of Pawtucket, R. I., died at his residence in that city April 19, 1888, of Tuberculosis Meningitis. He was born in Rehoboth, Mass., and was 51 years of age. While a citizen of Pawtucket he was chosen to fill several positions of trust and for eight years was assistant clerk, and clerk to the Water Board. In both positions his duties were performed with strict fidelity, and as he was an expert accountant the books of the office were kept in a manner which could but challenge admiration; in many other ways too he was an invaluable official. Upright in his dealings and courteous in bearing, he will be missed in personal and business relations by many who were glad to be counted among his acquaintances and friends. There is a touch of pathos in the fact that the funeral services were held from his beautiful house recently erected on Mineral Spring avenue. Rev. Dr. Bullen was the officiating clergyman, prominent state and city officials and many citizens of Pawtucket were in attendance and the floral tributes were numerous and beautiful. Mr. Horton was for many years a member of the First Baptist Church. He was elected to this Association in September 1887.

GENERAL STATISTICS.

	Population.	Date of Construction.	By whom owned.	Source of supply.	Mode of supply.	1 Builders of Pumping Machinery.	2 Description of Coal
Cochituate. BOSTON, MASS. Mystic.	370,000 105,000	1848 to 1864	City.	Lake Cochituate. Sudbury River. Mystic Lake.	Gravity 70 per ct. Pump 30 per ct.	H. R. Worthington. Boston Machine Co. H. R. Worthington.	Anthracite, Furn $4.94 to $5.87, 15½ per Bituminous, Brok $3.86 to $4.29, 8 9/10 per c
FALL RIVER, MASS.	64,000	1874	City.	Wattupa Lake.	Pump to Tank.	Boston Machine Co. H. R. Worthington. Davidson S. P. Co.	Cumberland, George's
NEW BEDFORD, MASS.	33,393	1866 to 1869	City.	Acushnet River.	Pump to Reservoir	Quintard Iron Wks[1] H. R. Worthington.[2] H. R. Worthington.[3] High Duty.	Anthracite, Lehi $5.00 to $5.48, 10 2/10 to per cent. ash. Wood
BAY CITY, MICH.	29,415	1872	City.	Saginaw Bay.	Direct Pumping	Holly Mfg. Co.	Pine Slabs and Edg 80 cents to $1.00 per
TAUNTON, MASS.	23,674	1876	City.	Ground water and Taunton river	Direct Pumping	Holly Mfg. Co.	Anthracite, Egg, Packe Est. ash 13 per cent.
WOONSOCKET, R. I.	19,000	1884	Town.	Crook Falls Brook.	Pump to Tank.	H. R. Worthington.	Bituminous Coal an Works Coke, $4.90 p Ash 13 63/100 per ct. Wo per cord, Coke 9c. per
BURLINGTON, VT.	13,357	1867 1868	City.	Lake Champlain.	Pump.	H. R. Worthington.	Anthracite, Grate, Pitts Mill Shavings, $38.50 p
WALTHAM, MASS.	14,609	1872 1873	City.	Filter Basin near Charles River.	Pump.	H. R. Worthington.	Anthracite, Egg, Phil and Reading. $6. 10 9/16 per cent. as
PLYMOUTH, MASS.	7,239	1885	Town.	Ponds.	Gravity and Pump.	H. R. Worthington.	Bituminous, $5.07 pe

Statistics for the year 1887 in form adopted by the New England Water Works Association.

Compiled by WILLARD KENT, C. E., Supt. W. W. Woonsocket, R. I.

PUMPING STATISTICS.

	Mode of supply.	1 Builders of Pumping Machinery.	2 Description of Coal used.	3 Coal consumed for the year in pounds.	4 Lbs. of wood / 3	5 Total fuel consumed for the year.	6 Total pumpage for the year in gallons.	7 Average static hd. against which pumps work.	8 Av'g dynamic hd. against which pumps work.	9 Number of gals. pumped per pound of coal.	10 Duty in foot pounds per 100 pounds of coal, no deductions.	11 Cost per million gallons into reservoir, figured on pumping expenses.	12 Cost per million gallons one foot high, figured on pumping expenses.	13 Cost per million gallons into reservoir, figured on total maintenance.	14 Cost per million gallons one foot high, figured on total maintenance.
nate.	Gravity 70 per ct.	H. R. Worthington.	Anthracite, Furnace,	2,541,900			1,255,981,200		115.88	494.1	47,752,800	9.68	$0.0835		
iver.	Boston Machine Co.		$4.94 to $5.87, 15¼ per ct. ash.		.....	.....		.....						.....	.....
ake.	Pump 30 per ct.	H. R. Worthington.	Bituminous, Broken, $3.86 to $4.29, $8\frac{9}{10}$ per cent. ash.	6,007,900			2,784,653,100		147.73	463.5	57,106,200	7.81	0.0529		
ake.	Pump to Tank.	Boston Machine Co. H. R. Worthington. Davidson S. P. Co.	Cumberland, George's Creek.	837 tons.	.....	.....	580,700,532	.....	185.4	309.6	.....	.....	.....	204.82	.....
iver.	Pump to Reservoir	Quintard Iron Wks[1] H. R. Worthington.[2] H. R. Worthington.[3] High Duty.	Anthracite, Lehigh, $5.00 to $5.48, $10\frac{2}{10}$ to $11\frac{5}{10}$ per per cent. ash. Wood, $3.80.	[1]392,360 [2]265,415 [3]1,133,831	1,450 501 657	393,810 265,916 1,134,488	220,337,172 121,455,608 754,340,094	125.4 125.1 125.6	133.9 126.2 127.5	562. 458. 665.	62,480,955 48,072,699 70,703,924	8.61	.06$\frac{4206}{10000}$	$67.51	0.52$\frac{477}{1000}$
Bay.	Direct Pumping	Holly Mfg. Co.	Pine Slabs and Edgings, 80 cents to $1.00 per cord.	7 tons.	2267¾ cords.	1,309,857	827,195,000	.....	109.15	631.	57,487,551	7.95	0.074	50.65	0.464
ater iver	Direct Pumping	Holly Mfg. Co.	Anthracite, Egg, Packer Lehigh, Est. ash 13 per cent. $5.45.	770,850		770,850	264,618,762	.....	151.3	343.	43,316,668	19.95	0.131	151.87	1.003
alls	Pump to Tank.	H. R. Worthington.	Bituminous Coal and Gas Works Coke, $4.90 per ton. Ash $13\frac{11}{100}$ per ct. Wood $3.00 per cord, Coke 9c. per bushel.	54,185	4,606	494,271	89,423,053	204.491	242.661	181.	36,614,271	28.715	0.118	217.73	0.90
ain.	Pump.	H. R. Worthington.	Anthracite, Grate, Pittson, $5.44. Mill Shavings, $38.50 per week.	.....	.....	.....	225,111,150	289.	316.	.....	....	33.65	0.1065	109.72	0.347
in ver.	Pump.	H. R. Worthington.	Anthracite, Egg, Philadelphia and Reading. $6.33. $10\frac{3}{10}$ per cent. ash.	717,600	.....	.....	198,609,670	164.	184.	277.	42,471,970	28.16	0.153	144.33	0.786
	Gravity and Pump.	H. R. Worthington.	Bituminous, $5.07 per ton.	496,510	.....	496,510	214,809,418	35.	90.	433.	32,474,061	10.17	0.113	49.99	0.55$\frac{54}{100}$

Comparative Financial Statement for 1887 from Reports adopting

MAINT

		Fall River, Mass.	Springfield, Mass.	New Bedford, Mass.	Holyoke, Mass.	Bay City, Mich.	Taunton, Mass.
RECEIPTS							
From Consumers.							
Rates domestic	A	83,286.00		41,521.74	54,357.73	14,757.21	29,665.24
" manufacturing	B		105,451.52	4,086.69		4,624.02	7,097.83
Net receipts	C	83,286.00		45,608.43	54,357.73	19,381.23	36,763.07
Miscellaneous	D	14,529.10	11,745.32	271.75	4,200.22	572.87	11.59
Total	E	97,815.10	117,196.84	45,880.18	58,557.95	19,954.10	36,774.66
From Public Funds.							
Hydrants	F	50,000.00	10,560.00		3,000.00		7,200.00
Fountains	G		1,675.00				904.05
Street Watering	H						850.00
Public Buildings	I		2,656.50		277.80		746.50
General Appropriations	J			89,800.00	3,081.17	40,160.00	
Gross Receipts	K	147,815.10	132,088.34	135,680.18	64,916.92	60,114.10	46,475.21
EXPENDITURES.							
Management & Repairs,	A.A.	31,224.29	35,445.05	26,208.05	8,743.86	11,019.29	15,963.86
Interest on Bonds	B.B.	96,410.00	82,000.00	47,800.00	15,000.00	30,880.00	24,223.00
Refunded Water Rates	*						
Total Maintenance	C.C.	127,634.29	117,445.05	74,008.05	23,743.86	41,899.29	40,186.86
Bonds Paid				30,000.00		10,000.00	
Balance	D.D.	20,180.81	14,642.29	31,672.13	41,173.06	8,214.81	6,288.35
Total	E.E.	147,815.10	132,088.34	135,680.18	64,916.92	60,114.10	46,475.21

...tement for 1887 from Reports adopting the form suggested by the New England Water Works Association.

MAINTENANCE.

Compiled by WILLARD KENT, C. E.
Supt. W. W., Woonsocket, R. I.

	New Bedford, Mass.	Holyoke, Mass.	Bay City, Mich.	Taunton, Mass.	Woonsocket, R. I.	Fitchburg, Mass.	Burlington, Vt.	New London, Conn.	Plymouth, Mass.	Waltham, Mass.	Trenton, N. J.	Boston.	
												Cochituate.	Mystic.
	41,521.74	54,357.73	14,757.21	29,665.24	10,490.45	23,230.42	25,707.22	23,182.36	14,249.35	30,664.90	66,467.22	605,297.06	177,118.19
.52	4,086.69		4,624.02	7,097.83	5 0.81	6,973.42	3,340.06		634.51	3,768.20		527,333.65	100,411.46
	45,608.43	54,357.73	19,381.23	36,763.07	10,940.26	30,203.84	29,047.28		14,883.86	34,433.10		1132630.71	277,529.65
.32	271.75	4,200.22	572.87	11.59	270.53		19.27		331.84	1,529.90	7,907.30	31,106.57	2,178.34
.84	45,880.18	58,557.95	19,954.10	36,774.66	11,210.79		29,066.55		15,215.70	35,963.00	74,374.52	1163737.28	279,707.99
.00		3,000.00		7,200.00	9,002.50	12,250.00	1,200.00	6,800.00		3,560.00	408.00	83,610.00	8,598.00
.00				904.05	965.54	750.00	75.00	100.00		340.00			
				850.00	189.33	800.00	250.00	800.00					3,925.09
.50		277.80		746.50	106.11	1,300.00	69.00	140.00		450.00		27,951.04	2,965.91
	89,800.00	3,081.17	40,160.00		6,806.20	15,963.93							
.34	135,680.18	64,916.92	60,114.10	46,475.21	28,280.47	61,467.77	30,660.55	31,022.36	15,215.70	40,313.00	74,782.52	1275298.32	295,196.99
.05	26,208.05	8,743.86	11,019.29	15,963.86	7,345.52	22,654.51	13,200.00	4,087.48	6,168.99	11,048.45	14,946.84	341,693.34	153,345.02
.00	47,800.00	15,000.00	30,880.00	24,223.00	12,124.90	27,487.50	11,490.00	17,500.00	4,570.00	18,080.00	15,850.00	721,584.76	44,927.50
												*553.59	*84,374.47
.05	74,008.05	23,743.86	41,899.29	40,186.86	19,470.42	50,142.01	24,690.20	21,587.48	10,738.99	29,128.45	30,796.84	1063831.69	282,646.99
	30,000.00		10,000.00										
.29	31,672.13	41,173.06	8,214.81	6,288.35	8,810.05	11,325.76	5,970.35	9,434 88	4,476.71	11,184.55	43,985.68	211,466.63	12,550.00
.34	135,680.18	64,916.92	60,114.10	46,475.21	28,280.47	61,467.77	30,660.55	31,022.36	15,215.70	40,313.00	74,782.52	1275298.32	285,196.99

Comparative Financial Statement for 1887 from Reports adopting the form suggested by th

CONSTRUCTION.

		Fall River, Mass.	Springfield, Mass.	New Bedford, Mass.	Holyoke, Mass.	Bay City, Mich.	Taunton, Mass.	Woonsocket, R.I.	Fitchburg, Mass.	Burlington, Vt.
RECEIPTS.										
From Bal. previous year	R	4,800.00		From previous year 26,105.81 fr'm main: 31,672.13	17,445.68	From previous year 785.01 Frm Maint. 8,214.81	2,189.84			
" Bonds issued	S						45,000.00			
" Appropriat'n tax levy	T	5,000.00	13,000.00					18,472.65	120,000.00	7,770.
" other sources	U		1,600.36	4,711.26			5,534.74	2,958.94	7,274.59	650.
Total	V	9,800.00	14,600.36	62,489.20	17,445.68	8,999.82	52,724.58	21,431.59	19,274.59	8,420.
EXPENDITURES.										
Extension mains	F.F.	9,144.12	14,600.36	26,949.77	14,081.61	2,977.53	8,967.38	3.948.84	8,762.01	2,162.
" services	G.G.			7,666.98	407.25		6,080.94	4,807.89	8,700.23	1,013.
" special	H.H.	607.02		4,441.80	2,956.82	606.43	36,835.16	12,674.86	1,554.65	5,244.
Total construction	I.I.			39,058.55	17,445.68	3,583.96	51.883.48			
Balances	J.J.	48.86		23,430.65		5,415.86	841.10		257.60	
Total	K.K.	9,800.00		62,489.20		8,999.82	52,724.58	21,431.59	19,274.59	8,420.
Net cost of works	W	1754441.96	1335534.98	1298460.76	480,373.75	430,361.29	551,187.90	319,871.72	621,701.02	324,351.
Bonded debt	X	1700000.00	1200000.00	790,000.00	250,000.00	367,000.00	523,700.00	300,000.00	500,000,00	231,500.
Value of Sinking Fund	Y	160,327.30			100,000.00		181,132.82		150,100.99	97,850.
Rate of Interest (per cent.)	Z	$5\frac{7}{16}$	7. & 6.	5.81		8.	4., $4\frac{1}{2}$., 6.	4.	5.55	4. and

form suggested by the New England Water Works Association.

CTION.

Compiled by WILLARD KENT, C. E.
Supt. W. W., Woonsocket, R. I.

Woonsocket, R. I.	Fitchburg, Mass.	Burlington, Vt.	New London, Conn.	Plymouth, Mass.	Waltham, Mass.	Trenton, N. J.	Boston.	
							Cochituate.	Mystic.
					2,128.58	2,591.22		
				34,603.80	12,000.00			
472.65	120,000.00	7,770.33						
958.94	7,274.59	650.12	9,434.88	9,492.93	2,315.15	21,000.00		
431.59	19,274.59	8,420.45	9,434.88	44,096.73	16,443.73	23,591.22		
948.84	8,762.01	2,162.73	5,730.23	36,353.18		17,833.84	234,389.52	2,180.40
807.89	8,700.23	1,013.43	1,740.47	239.34			36,405.00	
674.86	1,554.65	5,244.29	265.46	7,504.21		5,160.89	283,072.77	
			7,736.16	44,096.73	11,734.73		553,867.29	2,180.40
	257.60		1,698.72		4,709.00	596.49		
431.59	19,274.59	8,420.45	9,434.88		16,443.73	23,591.22		
871.72	621,701.02	324,351.10	337,307.73		388,000.00	445,946.12	1952748332	1659039.37
000.00	500,000,00	231,500.00	250,000.00	141,000.00	373,000.00	265,000.00		
	150,100.99	97,850.00		8,257.95	25,910.59	211,817.92		
.	5.55	4. and 6.	7.	4., 4½., 5., 6.	4. and 6.6	5. and 6.		

Comparative Statement of the CONSUMPTION in various places, for the year 1887, in form adopted by the New England Water Works Association.

Compiled by WILLARD KENT, C. E., Supt. W. W. Woonsocket, R. I.

NAME OF PLACE.	1 Estimated total population at date.	2 Estimated population on line of pipe.	3 Es'm'ted population supplied at date.	4 Total number of gallons consumed for the year.	5 Passed through domestic meters.	6 Passed thro'gh manufacturing meters.	7 Average daily consumption in gallons.	8 Gallons per day to each inhabitant.	9 Gallons per day to each consumer.	10 Gallons per day to each tap.
Boston, Mass..										
Cochituate.	370,000		360,000	10,896,008,000	280,785,000	2,358,052,500	29,852,100	80.8	82 9	540
Mystic.	105,000		103,000	2,784,595,000	12,911,250	442,678,400	7,629,000	72.7	74 1	454
Fall River, Mass.	64,000		60,000	580,700,532	244,410,020		1,590,960	24.86	26.89	379
Springfield, Mass.	40,000	34,500	29,800	1,460,000,000	102,699,803		4,000,000	100.	134.	830
New Bedford, Mass.	36,000	31,750	30,080	1,112,302,789	2,852,326	189,165,274	3,047,404	85.	101.	555
Holyoke, Mass.	31,348	30,848	30,640	820,017,268	156,569,708		2,246,622	71.66	73.03	1034
Bay City, Mich.	33,000	16,000	10,500	827,195,009	25,948,789	46,527,230	2,266,288	69.	216.	1701
Taunton, Mass.	23,674	21,400	19,000	264,618,762	32,446,357	68,672,071	724,982	31.	38.	252
Woonsocket, R. I.	19,500	16,200	7,755	88,924,946	22,050,330	12,588,195	243,565	12.49	31.41	409
Fitchburg, Mass.	20,000	18,000	14,000	432,000,000	17,596,000	104,601,301	1,183,500	59.	84.	537
Burlington, Vt.	14,000	13,700	13,400	225,111,150	22,439,200	9,496,570	616,743	44.	46.	263
New London, Conn.	13,000	11,300	9,327	400,000,000			1,100,000	84.6	118.	626
Plymouth, Mass.	7,500	6,500	6,400	214,809,418			588,519	78.	92.	447
Waltham, Mass.	16,000	14,500	13,500	198,609,670	14,877,456		544,138	34.	40.3	266.4

DISTRIBUTION.

Statistics relating to MAIN PIPE work in various places for the year 1887 in form adopted by the New England Water Works Association.

Compiled by WILLARD KENT, C. E. Supt. W. W. Woonsocket, R. I.

NAME OF PLACE.	1 Kind of pipe used.	2 Size of Distribution pipe in inches.	3 Distribution pipe extended during 1887.	4 Distribution pipe discontinued during 1887.	5 Total length of distribution pipe above 4 inches in miles.	6 Cost of repairs per mile.	7 Number of leaks per mile during 1887.	8 Total length of distribution pipe less than 4 inch in mile.	9 Hydrants added during 1887.	10 No. of Hydrants now in use.	11 Stop gates added	12 Number of stop gates above 4 in. now in use.	13 No. of stop gates less than 4 inch.	14 Number of blow off gates.	15 Range of pressure at center for day and night in lbs.
Boston, [Cochituate]	Cast Iron.	48 to 4	22.36 miles		436.5				184	4990	249	4667			
" [Mystic.]	C. I., W. I. C. L.	30 to 3	4.51 "		137.76			6.2	43	935	65	1301			
Fall River, Mass.	Cast Iron.	24 to 6			59.73				7	613	5	617			80
Springfield, Mass.	Wrought Iron, W. I. C. L., C. I.	30 to 3	5.38 "	2.48	81.55		1.39		38	528	27	723	161	70	‡90 to 120 ‖30 to 35
New Bedford, Mass.	W. I. C. L. and Cast Iron.	30 to 4	2.85 "	0.54	54.3782	$21.19	.202	1.1	21	410	38	547	59	54	29 to 37
Holyoke, Mass.	Wrought Iron, Cast Iron.	20 to ½	13,456 ft.	3,156	42.39	1.53	.188	25900f	13	274	32	298	0	12	day, 45 to 65 night, 80 to 100
Bay City, Mich.	Cast Iron, Wyckoff Pat.	20 to 3	4,108¼ "	37½ ft.	25.5	26.21	1.25	319 ft	10	190	12	360	3	19	28 to 33
Taunton, Mass.	Cast Iron.	20 to 4	1.71 miles	0	54.62	50.06	0	4108 ft	13	470	29	347	6	24	45 to 50
Woonsocket, R. I.	Cast Iron.	14 to 4	3680.91 ft.	0	18.963	13.15	1.21	0	14	284	12	216	2	13	95 to 105
Fitchburg, Mass.	W. I. C. L., Cast Iron.	16 to 2	13,504 "	1,363	34.77	*116.29 †1.19	1.24	1.73m	11	256	61	230	20	7	‡155 to 160 ‖78 to 80
Burlington, Vt.	C. L., W. I.. C. I.	10 to ½	4,423 "	1,577	29.58	20.30	1.2	27697f	1	162	6	263	67	5	70 to 85
New London, Conn.	W. I. C. L., C. I.	16 to 4	4,340 "	0	25.8	24.94	1.5	10357	6	136	6	108		17	32 to 55
Plymouth, Mass.	W. I. C. L.	20 to 2	21,015 "	1,203	27.33	13.35	1.82	7.67m	8	75	35	217	90	21	55
Waltham, Mass.	C. I., W. I. C. L.	16 to 2	8,747 "		34.3	5.13	.36		10	188	34				

*Cement Lined. †Cast Iron. ‡High Service. ‖Low Service.

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*Cement Lined. †Cast Iron. ‡High Service. ‖Low Service.

DISTRIBUTION.

Statistics relating to SERVICE PIPE work in the various places for the year 1887, in form adopted by the New England Water Works Association.

Compiled by WILLARD KENT, C. E., Supt. W. W. Woonsocket, R. I.

NAME OF PLACE.	16 Kind of Pipe used.	17 Size of service pipe in inches.	18 Length of service pipe extended.	19 Length of service pipe discontinued	20 Total length of service pipe now in use, in miles.	21 Taps added during 1887.	22 Number of taps now in use.	23 Average length of service.	24 Average cost of service.	25 Meters added during 1887.	26a Domestic meters now in use.	26b Manufacturing meters now in use.	27 Motors and elevators added during 1887.	28 No. of motors and elevators now in use.
Boston, [Cochituate]	Lead	⅝-1½ to 2	53,995			1835	55,235			3,114				365
[Mystic]	Lead and Wt. Iron	⅝-1½ to 2	21,851			694	16,804			420				8
Fall River, Mass.	Lead	½ to 2				211	4,197			216	2941			6
Springfield, Mass.		½ to 4				300	4,819			123	472		1	99
New Bedford, Mass.	Lead & Cast Iron.	½-⅝ to 8	9,492½		31.8	270	5,495	35.2	gro's 21.49 net $7.26	22	60	42	4	28
Holyoke, Mass.	Cem't, Rub. lined	¾-⅝ to 4	2,700		43460 ft.	135	2,173	20.	11.94	9	149		3	54
	Enam'd & C. Iron											71		
Bay City, Mich.	Lead, Iron, Wyck.	⅝ to 8				64	1,332			16	109	test 10	6	8
Taunton, Mass.	C. lined., Wt. Iron	¾-⅝-½ to 1½	1.56 mls	639 ft.	27.78	159	2,875		gro's 23.77 net $12.89	96	718	58	2	7
Woonsocket, R. I.	Lead	¾-⅝-½ to 4	2,590	44	9492 ft.	160	595	15.9	12.59	172	520	16	1	1
Fitchburg, Mass.	W. I., C., Cst. Iron	¾-⅝-½ to 6	10,339		26.88	204	2,203	50.68	net 7.02	92	464	81	4	15
Burlington, Vt.	Gavl. Iron, Lead..	¾-⅝-½ to 4	2,638	146	12.95	101	2,338	27.2	10.34	112	338	36	1	7
New London, Conn.	Wt. I., C. lined,.	¾-⅝-½ to 4	1,956	107	6.15	103	1,755	18.05	12.41	4	40		2	13
	Galv. C. I., Lead.													
Plymouth, Mass.	Lead, C. lined....	½-¾-1	660		5.00	33	1,317	20.00	5.33					2
Waltham, Mass.	Cast Iron, Wt. Iron	¾-½ to 6	8992.5	133	22.6	155	2,042	54.2	12.00	3	23		4	8
	Cement lined.....													

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